BANDWIDTH STUDY OF MICROSTRIP REFLECTARRAY AND A NOVEL PHASED REFLECTARRAY CONCEPT

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***Introduction*:** A microstrip reflectarray[1,2] is a flat reflector antenna that can bc conformally mounted onto its supporting structure without consuming a significant amount of real estate and without adding significant mass. This antenna, configured as in Figure 1, is currently finding applications in satellite communications and commercial usages. For examples, high-gain antennas with small volume and low mass are needed in microspacecraft development, and wall-mounted flat antennas arc desired for Direct Broadeast Satellite (DBS) application. Conventional high-gain antennas most often used are parabolic reflectors. Although they are efficient radiators, due to their curved shapes, parabolic reflectors arc generally bulky in size and large in mass. It is known that when a required antenna gain is given at a particular frequency, the antenna aperture size is more or lcss fixed. The only significant size reduction that may be achieved for an antenna is its profile thickness. The microstrip reflectarray offers such an advantage of profile size reduction as compared to a conventional parabolic reflector. In addition, the microstrip reflectarray has several other significant advantages, For examples, the main beam of the reflectarray can bc designed to tilt to large angles from its broadside direct ion, its printing fabrication process yields lower manufacturing cost, and it can be easily folded for packaging and transportation since it is a flat structure.

Currently, the printed microstrip reflectarray comes in three slightly different forms. One, shown in Figure 1, uscs identical patches with different-length transmission delay lines attached to compensate for the spatial phase delays [2,3,4,5]. The second form uses variable-size patches to achieve the required phase delays without any transmission line attached to the patch [6], The third form employs variable-size printed dipoles without transmission lines attached [7]. This article will concentrate on the bandwidth study of the first form. It is expected that the bandwidths of the other two forms will bc of the same order of magnitude. Regardless of their forms, they all suffer from one major shortcoming which is their limited bandwidths which are no match to that of a parabolic reflector with theoretically an infinte bandwidth. A new concept of mechanically phased reflectarray is also presented in this article.

Bandwidth study: ***The*** bandwidth performance of a microstrip reflectarray is limited primarily by two factors. One is the narrow bandwidth of the microstrip patch element and the other is the differential spatial phase delay, The microstrip patch clement generally has a bandwidth of about 3°/0. To achieve wider bandwidth, techniques such as using thick substrate for the patch, stacking multiple patches, and using sequential y rotated subarray clements have been employed. More than 15% bandwidths for microstrip antennas have been reported. The second bandwidth limiting factor, differential spatial phase delay, has not been fully reported and can be best explained by referring to Figure 2.. The differential spatial phase delay, AS, is the difference between the electrical paths S 1 and S2. This AS can bc many

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multiples of the wavelength at the center operating frequency. It can be expressed as AS = $(N+d)\lambda$ where N is an integer and d is a fractional number of a free-space wavelength λ. At each patch location, d is compensated by an appropriate length of a phase delay line attached to the patch, As frequency changes, the factor $(N+d)\lambda$ becomes $(N+d)(\lambda+\Delta\lambda)$. Since the lengths of the phase delay lines arc fixed, a frequency excursion error will occur in the rc-radiated phase front. The amount of phase change in each path is $(N+d)\Delta\lambda$ which canbcasignificant portion of a wavelength (3600). To reduce the amount of frequency excursion error, the integer number N must bc reduced. There arc three ways to reduce N. One is to design the reflectarray with a larger f/D ratio. The second way is simply to avoid the usc of a reflectarray with a large electrical diameter. The effect of f/D ratio and diameter on bandwidth performances are calculated by the array theory [2] and are given in Figures 3 and 4. The calculated radiation patterns at several frequencies arc illustrated in Figures 5 and 6, where the pattern defocusing effect as frequency deviates from the center frequency is clearly demonstrated. The third way to reduce frequency excursion error is to usc time delay lines instead of phase delay lines. The time delay line method, in general, should bc able to achieve more than an octave of bandwidth, but will suffer from higher insertion loss due to the required long transmission lines.

Phased reflectarray: A circularly polarized microstrip reflectarray can be achieved by having two equal-length delay lines orthogonally attached to each patch with a circularly polarized feed horn, The length of these delay lines are different from element to element to compensate for the different spatial phase delays. In a ncw configuration proposed here, the required phase delay compensations for all elements of the reflectarray arc achieved by rotating the elements to different angular orientations as shown in Figure 7. Except for the rotations, all elements are identical with identical delay lines. In this case, the delay lines will serve only as angular references and not for phase delay compensation. This technique of rotating the circularly polarized elements to achieve the required phases has been dcmonst rated [8] previously for a conventional array. If a miniature motor is placed under each patch element of this microstrip reflectarray, then all the motors under the patches can bc controlled to scan the beam to different directions. Since all the elements in this phased reflectarray are physically isolated from each other (without any RF power division network), no rotary joint is needed; which implies reduced cost and enhanced reliability. The use of miniature motors will eliminate the need for high-cost phase shifters for beam scanning. Consequentl y, a very large phased array antenna system with relatively low cost may bc realizable.

References:

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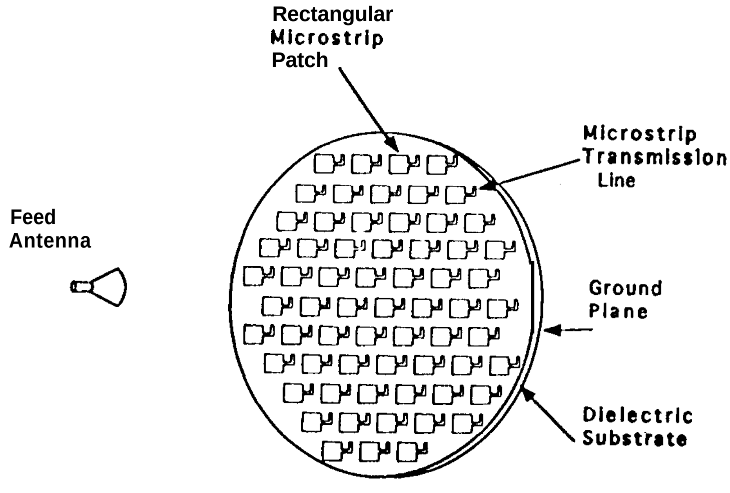

Figure 1, Microstrip reflectarray with identical patches but different-length phase delay transmission lines.

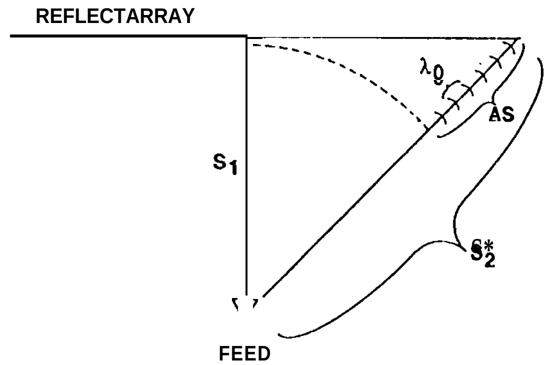

Figure 2. Differential spatial phase delay of reflectarray.

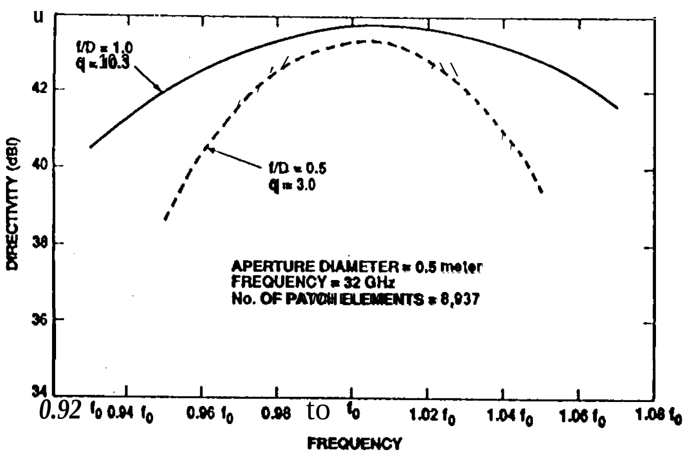

Figure 3. Directivity versus frequency for a 0,5m diameter **Ka-band reflectarray. "q" is the feed cos(θ)**q** power factor.

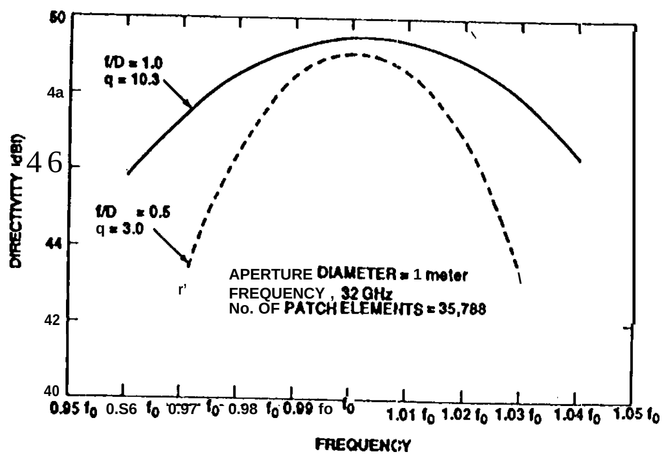

Figure 4. Dirctivity versus frequency for a 1.0m diameter **Ka-band reflectarray**.

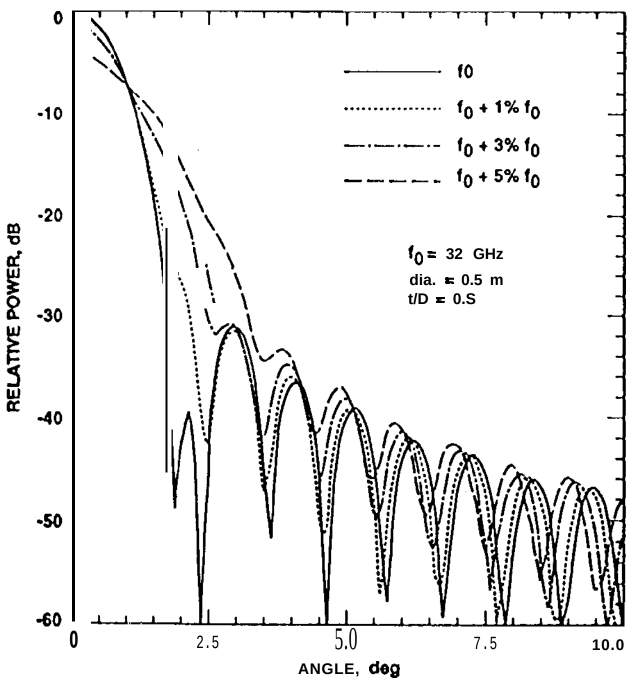

Figure 5. Calculated **reflectarray** patterns at several frequencies; **f/D**=0.5, number of **elements=8,937**.

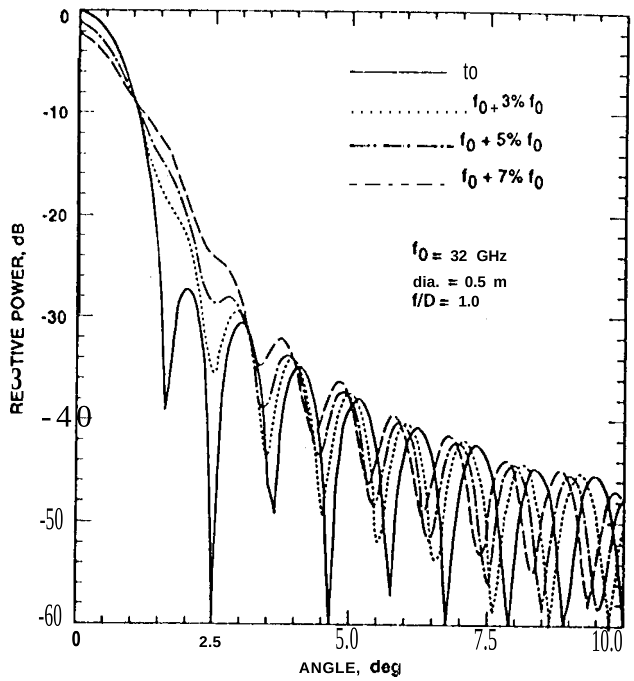

Figure **6**. Calculated **reflectarray** patterns at several frequencies; **f/D**= 1.0, number of **elements=35,788**.

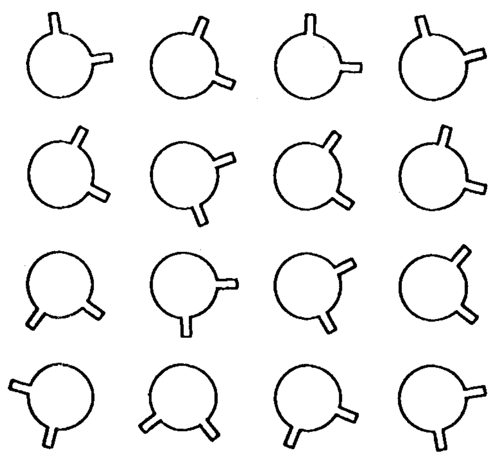

Figure 7. **Reflectarray** phase delay compensation by rotation of identical **CP** elements.

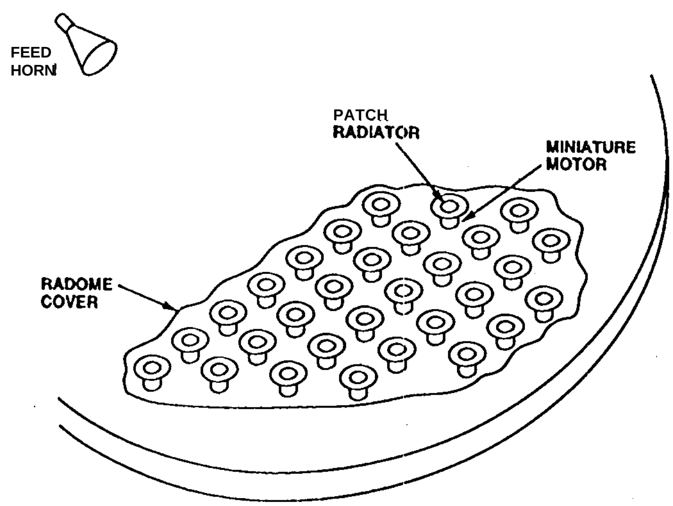

Figure 8. Mechanically phased **reflectarray**; beam scan by mechanical rotation of **CP** elements.